

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

REC'D 25 OCT 2005

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference XA1765	FOR FURTHER ACTION		See Form PCT/IPEA/416
International application No. PCT/GB2004/004670	International filing date (day/month/year) 04.11.2004	Priority date (day/month/year) 07.11.2003	
International Patent Classification (IPC) or national classification and IPC C01B31/02			
Applicant BAE SYSTEMS PLC et al.			

<ol style="list-style-type: none"> This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36. This REPORT consists of a total of 5 sheets, including this cover sheet. This report is also accompanied by ANNEXES, comprising: <ol style="list-style-type: none"> <input checked="" type="checkbox"/> (<i>sent to the applicant and to the International Bureau</i>) a total of 4 sheets, as follows: <ul style="list-style-type: none"> <input checked="" type="checkbox"/> sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions). <input type="checkbox"/> sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box. <input type="checkbox"/> (<i>sent to the International Bureau only</i>) a total of (indicate type and number of electronic carrier(s)), containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).
<ol style="list-style-type: none"> This report contains indications relating to the following items: <ul style="list-style-type: none"> <input checked="" type="checkbox"/> Box No. I Basis of the opinion <input type="checkbox"/> Box No. II Priority <input type="checkbox"/> Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability <input type="checkbox"/> Box No. IV Lack of unity of invention <input checked="" type="checkbox"/> Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement <input type="checkbox"/> Box No. VI Certain documents cited <input type="checkbox"/> Box No. VII Certain defects in the international application <input type="checkbox"/> Box No. VIII Certain observations on the international application

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/GB2004/004670

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.
 - This report is based on translations from the original language into the following language, which is the language of a translation furnished for the purposes of:
 - international search (under Rules 12.3 and 23.1(b))
 - publication of the international application (under Rule 12.4)
 - international preliminary examination (under Rules 55.2 and/or 55.3)
2. With regard to the **elements*** of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):

Description, Pages

1-17 as originally filed

Claims, Numbers

1-22 received on 15.08.2005 with letter of 15.08.2005

Drawings, Sheets

1/7-7/7 as originally filed

a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

- The amendments have resulted in the cancellation of:
 - the description, pages
 - the claims, Nos.
 - the drawings, sheets/figs
 - the sequence listing (*specify*):
 - any table(s) related to sequence listing (*specify*):
- This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
 - the description, pages
 - the claims, Nos.
 - the drawings, sheets/figs
 - the sequence listing (*specify*):
 - any table(s) related to sequence listing (*specify*):

* If item 4 applies, some or all of these sheets may be marked "superseded."

**INTERNATIONAL PRELIMINARY REPORT
ON PATENTABILITY**

International application No.
PCT/GB2004/004670

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-22
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-22
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-22
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

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Re Item V

**Reasoned statement with regard to novelty, inventive step or industrial applicability;
citations and explanations supporting such statement**

Reference is made to the following documents:

- D1: A.A. Setlur et.al. " A method for synthesizing large quantities of carbon nanotubes and encapsulated copper nanowires ", Applied Physics Letters , Vol. 69, No. 3, pp. 345-347 (15 July 1996).
- D2: Takeo Oku and Katsuaki Suganuma, "One-dimensional positioning of carbon nanocapsules and spontaneous formation of carbon nanotubes by self-organization of gold nanoparticles", Microelectronic Engineering, Vol. 51-52, pp. 51-60 (May 2000)

Independent Process Claim 1

The document D2 is regarded as being the closest prior art to the subject-matter of claim 1, and describes a process of forming a nanowire in four steps: providing nanoparticles, providing a molecular fluid, depositing the molecules from the fluid on the nanoparticles and joining further nanoparticles to the first to assemble a nanowire, according to steps (a) to (d) of claim 1.

The subject-matter of claim 1 differs from this known process in that the molecular fluid is in the form of a *vapour of molecules* and is therefore new (Article 33(2) PCT).

The problem to be solved by the present invention may be regarded as increasing the degree of control in nanowire fabrication.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) because a molecular vapour enables the speed of growth to be precisely controlled and thus gives more accurate structural control in nanowire fabrication.

Further document D1 describes a process to make nanowires from precursors for both the

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nanoparticles and the fluid of molecules but the entire process takes place in one step and is therefore less controlled than that of the invention.

Claims 1 to 18 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Independent Process Claim 19

The subject-matter of claim 19 differs from the process described in D2 in that a fluid of *halogenated* molecules is used from which hollow *nanotubes* are grown by an initial nucleation on the nanoparticles.

The subject-matter of claim 19 is therefore new (Article 33(2) PCT).

The problem to be solved by the present invention may be regarded as finding an alternative molecular source which conveniently produces nanotubes using the catalytic property of a nanoparticle.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) because halogenated molecules may originate from a solid polymer source and react with the nucleating nanoparticle surface more efficiently than non-halogenated molecules. These features increase the ease of nanotube assembly.

Claims 20 to 22 are dependent on claim 19 and as such also meets the requirements of the PCT with respect to novelty and inventive step.

Claims 1 to 23 are industrially applicable (Article 33(4) PCT).

XA1765PCT.amended claims

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Claims

1. A method of forming a nanowire comprising:
 - (a) providing an arrangement of nanoparticles comprising a first material;
 - (b) providing a vapour of molecules;
 - (c) depositing at least some second material from said fluid of molecules onto an exterior surface of one of said nanoparticles to form a deposit which surrounds at least part of the exterior of said one nanoparticle; and
 - (d) assembling more of said first material from said nanoparticles with said one nanoparticle to produce an elongate configuration of said first material in the form of a nanowire.

10 2. A method of forming a nanowire according to claim 1, wherein
15 said first material is a ferromagnetic material.

20 3. A method of forming a nanowire according to claim 2, wherein the ferromagnetic material is selected from the group consisting of the metals cobalt, nickel, platinum, palladium and iron, and the alloys containing at least one of said metals.

4. A method of forming a nanowire according to any preceding claim, wherein the second material comprises carbon.

25 5. A method of forming a nanowire according to claim 4, wherein said fluid of molecules comprises fluorocarbon molecules.

30 6. A method of forming a nanowire according to any preceding claim, wherein said fluid of molecules comprises decomposition products produced from a polymer.

XA1765PCT.amended claims

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7. A method of forming a nanowire according to claim 6, wherein the method comprises applying a temperature sufficient to decompose the polymer to form a vapour and insufficient to cause coalescence of the nanoparticles.

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8. A method of forming a nanowire according to claim 7, wherein the temperature is below 600°C.

9. A method of forming a nanowire according to claim 7 or 8,
10 wherein the temperature is above 100°C.

10. A method of forming a nanowire according to claim 8 and 9, wherein the temperature is approximately 375°C.

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11. A method of forming a nanowire according to any preceding claim, wherein said nanoparticles catalytically assist a decomposition process, said decomposition process providing the material to form the deposit of second material around said one particle.

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12. A method of forming a nanowire according to any preceding claim, comprising depositing at least some of the second material to form a deposit which surrounds the sides of said nanowire.

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13. A method of forming a nanowire according to claim 12, wherein the nanoparticles comprise carbon and the method further comprises an annealing process which causes the carbon from the nanoparticles in the nanowire to migrate into the second material surrounding the nanowire.

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14. A method of forming a nanowire according to any preceding claim, wherein the deposit of second material comprises graphite, defective graphite, amorphous carbon and/or carbon fiber.

XA1765PCT.amended claims

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15. A method of forming a nanowire according to claim 14, wherein the deposit of second material comprises a plurality of layers of graphite and/or defective graphite.

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16. A method of forming a nanowire according to any preceding claim, wherein the nanowire is substantially linear.

10 17. A method of forming a nanowire according to any preceding claim, wherein the nanoparticles are provided in the form of an agglomerated mass of nanoparticles.

15 18. A method of forming a nanowire according to claim 17, wherein a plurality of different nanowires is formed from a single agglomerated mass of nanoparticles.

19. A method of forming a nanotube comprising:
20 (a) providing an arrangement of nanoparticles comprising a first material;
(b) providing a fluid of halogenated molecules;
(c) depositing at least some second material from said halogenated molecules onto an exterior surface of one of said nanoparticles to form a first deposit of second material which surrounds at least part of the exterior of said one nanoparticle; and
25 (d) depositing at least some further second material from said halogenated molecules so as to attach a second deposit of said second material onto said first deposit, to produce an arrangement of deposits in the form of a nanotube.

XA1765PCT.amended claims

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20. A method of forming a nanotube according to claim 19, wherein the fluid of halogenated molecules comprises decomposition products produced from a polymer.

5 21. A method of forming a nanowire, substantially as hereinbefore described.

22. A method of forming a nanotube, substantially as hereinbefore described.

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